Evaluation of orifice passage efficiency and descaling with an extended-length bar screen, new vertical barrier screen, and inlet flow vane at Lower Granite Dam, 1995

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Coastal Zone and Estuarine Studies Division

Northwest Fisheries Science Center

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Seattle, Washington

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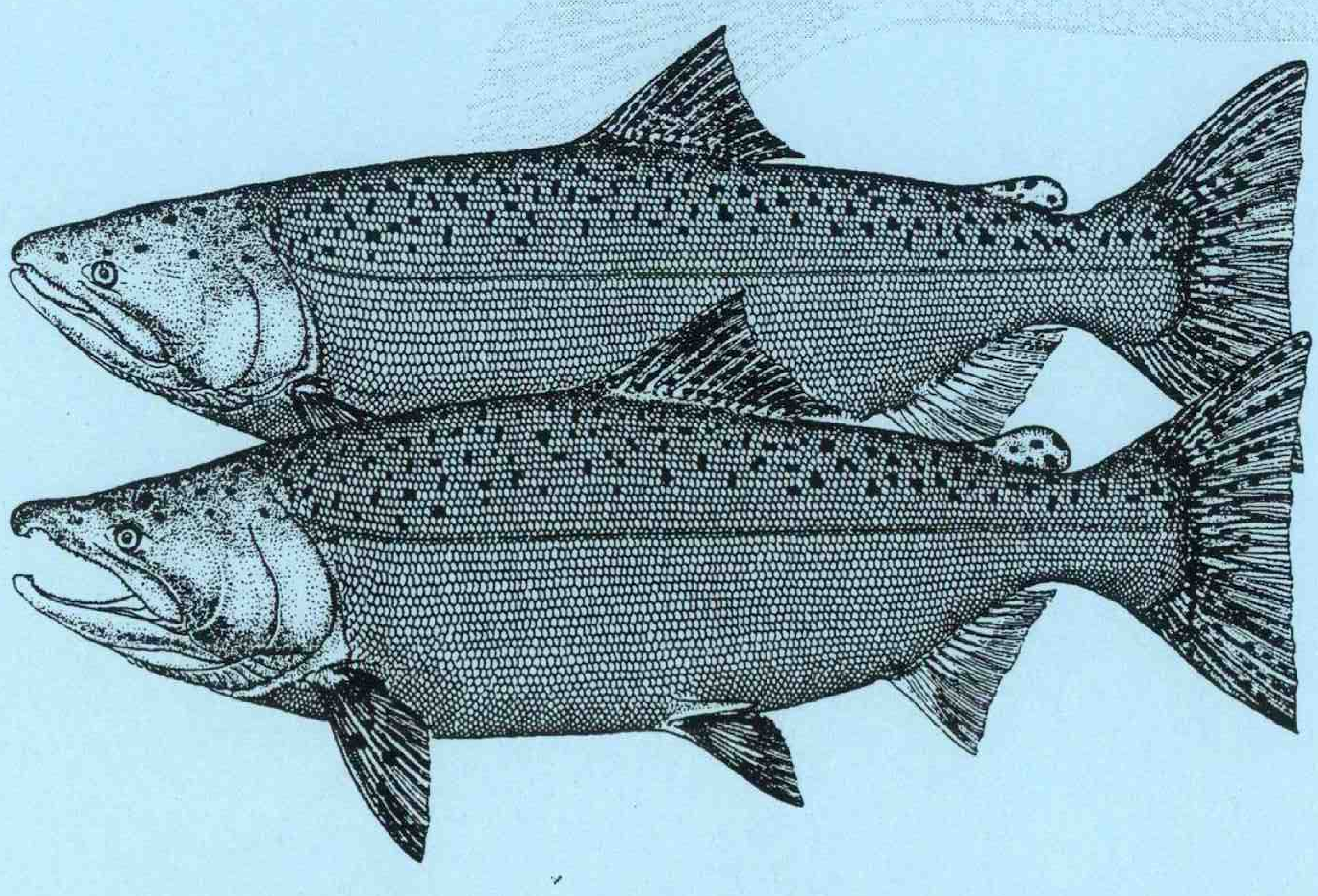

EVALUATION OF ORIFICE PASSAGE EFFICIENCY AND DESCALING WITH AN EXTENDED-LENGTH BAR SCREEN, NEW VERTICAL BARRIER SCREEN, AND INLET FLOW VANE AT LOWER GRANITE DAM, 1995

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EXECUTIVE SUMMARY

Tests were conducted in Turbine Unit 4 of Lower Granite Dam to evaluate orifice passage efficiency (OPE) and descaling of juvenile salmonids with a prototype extended-length submersible bar screen, newly designed vertical barrier screen (VBS2), and inlet flow vane. Orifice traps and PIT-tagged release groups were used to measure OPE of the north and south orifices of Slot 4B. Juvenile salmonids were collected from Slots 4B and 5B (which contained a standard-length submersible bar screen) to measure and compare descaling. Based on the results of these tests, we determined the following:

1) With an extended-length submersible bar screen, VBS2, and inlet flow vane, OPE was over 90% for yearling chinook salmon and steelhead. There was no statistically significant difference in OPE between the north and south orifices.

2) Descaling with the test guidance devices was low (<1% for yearling chinook salmon and <4% for steelhead) and was not significantly different from descaling with a standard-length submersible traveling screen.

3) Orifice trap results indicated that approximately 50% of the daily juvenile salmonid passage occurred between 2000 h and midnight.

4) The results of PIT-tagged release groups indicated that neither yearling chinook salmon nor steelhead were delaying in the collection channel.

INTRODUCTION

Since the early 1970s, the National Marine Fisheries Service (NMFS) and the U.S. Army Corps of Engineers (COE) have been investigating means to divert juvenile salmonids (*Oncorhynchus* spp.) away from turbines at dams on the Snake and Columbia Rivers (Matthews et al. 1977, Gessel et al. 1991). To accomplish this, submersible screens installed in turbine intakes divert juvenile salmonids into gatewells (Fig. 1). Fish then exit the gatewell through 10-inch- or 12-inch-diameter orifices, move through the collection channel and into a pressurized pipe or open flume, and then are either diverted back to the river or collected for transportation by barge or truck to a release site below Bonneville Dam on the lower Columbia River.

To improve the effectiveness of these juvenile passage systems, NMFS and the COE have researched methods of improving both fish guidance efficiency (FGE), or the percentage of fish entering a turbine intake that are guided by the screens, and orifice passage efficiency (OPE), which is the percentage of guided fish that pass from the gatewell to the collection channel in 24 hours. In studies at Lower Granite Dam from 1982 to 1984, FGE ranged from 45 to 57% for yearling chinook salmon (*O. tshawytscha*), well below the target level of 75% (Swan et al. 1983, 1984, 1985). Therefore, to improve FGE to levels higher than those attainable with the standard-length submersible traveling screen (STS), studies were conducted from 1987 to 1989 to test the concept of an extended-length screen (Ledgerwood et al. 1988, Swan et al. 1990). Because of the encouraging results of this research and of later extended-length screen studies at McNary (Brege et al. 1992; McComas et al. 1993, 1994, 1995), The Dalles (Brege et al. 1994, Absolon et al. 1995), and Little Goose (Gessel et al. 1994, 1995) Dams, the COE has proposed the

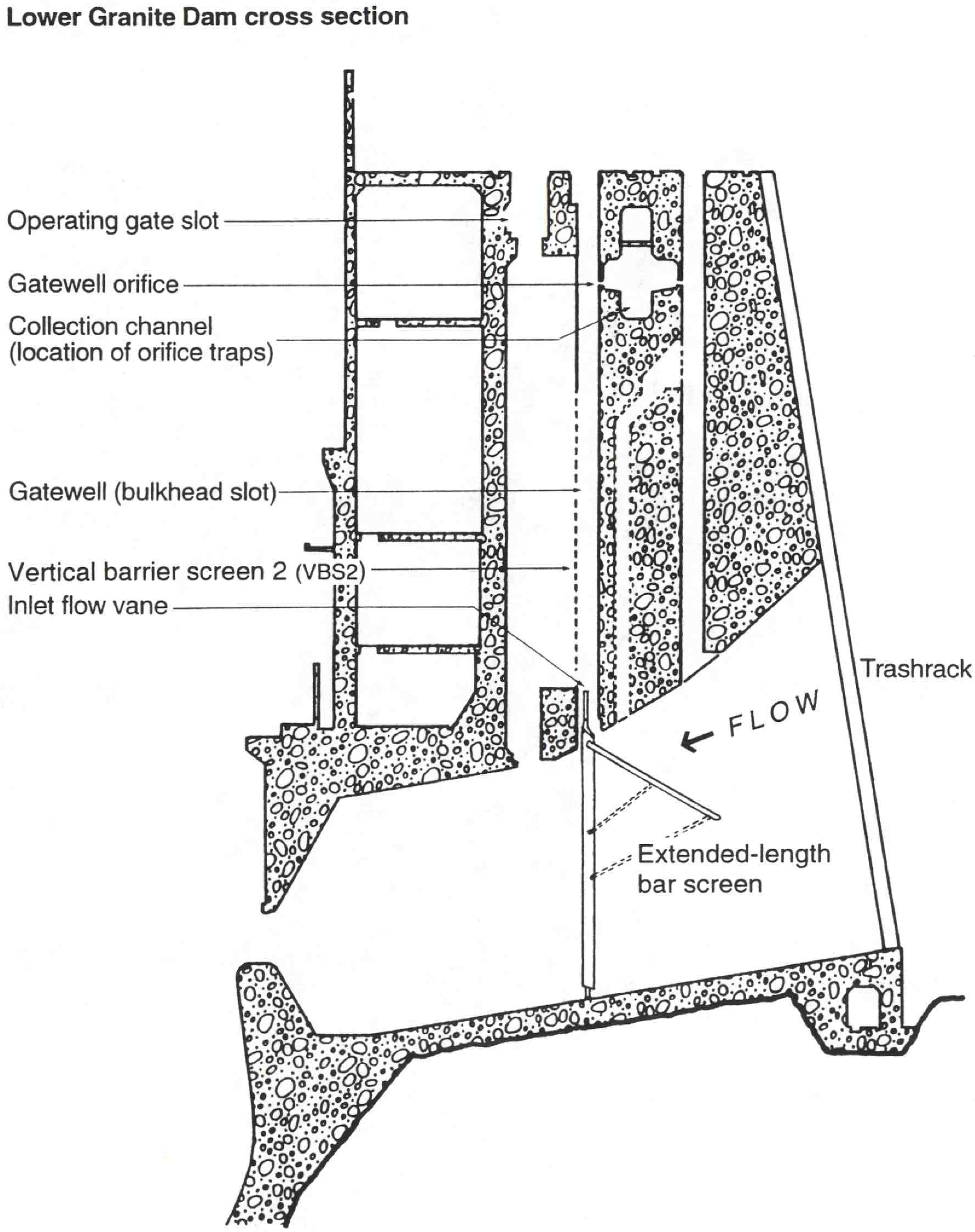

Figure 1. Cross section of turbine unit at Lower Granite Dam showing juvenile fish bypass system including extended-length bar screen, vertical barrier screen (VBS2), gatewell orifice, and collection channel. Also shown is location of orifice trap used in 1995 research.

installation of extended-length submersible bar screens (ESBSs) and newly designed vertical barrier screens in turbine units at Lower Granite Dam.

In 1982, an evaluation of the standard 0.2 m (8-inch) diameter orifices (two per gatewell) in use at Lower Granite Dam resulted in unacceptably low OPE levels for yearling chinook salmon (58%) and steelhead *(O. mykiss)* (30%) (Swan et al. 1983). Testing of a single 0.3 m (12-inch)-diameter orifice in lieu of the standard two 0.2 m-diameter orifices resulted in an OPE of 74% for yearling chinook salmon and 52% for steelhead (Swan et al. 1984). However, in 1985, OPE values of 98% for yearling chinook salmon and 86% for steelhead were achieved using a single 0.3 m-diameter orifice, a modified vertical barrier screen (VBS) and an operating gate raised 19 m (62 ft) above the normal stored position. In 1986, two 0.25 m (10-inch) orifices were installed in each of the gatewells at Lower Granite Dam; however, only one of these is operated per gatewell during the juvenile salmon outmigration.

For tests conducted at Lower Granite Dam in 1995, a prototype ESBS, VBS (VBS2, McComas et al. 1995), beam extension (to eliminate the increased gap between the intake ceiling and the downstream end of the ESBS), and inlet flow vane were installed in all three slots of Turbine Unit 4 (Figs. 1 and 2). In addition, all three operating gates were removed from Unit 4 to increase flows into the gatewell. For all tests, the forebay elevation was held at 733 to 734 (M.S.L.) with a net head of 97 to 98 ft. Discharge in test turbine units was maintained at 510 m^3/s (18,000 cfs).

Because ESBSs and the new VBS systems create higher flows and different current patterns within the gatewell, the first objective of 1995 research was to measure and compare OPE in the north and south orifices of the test gatewell (4B). The second

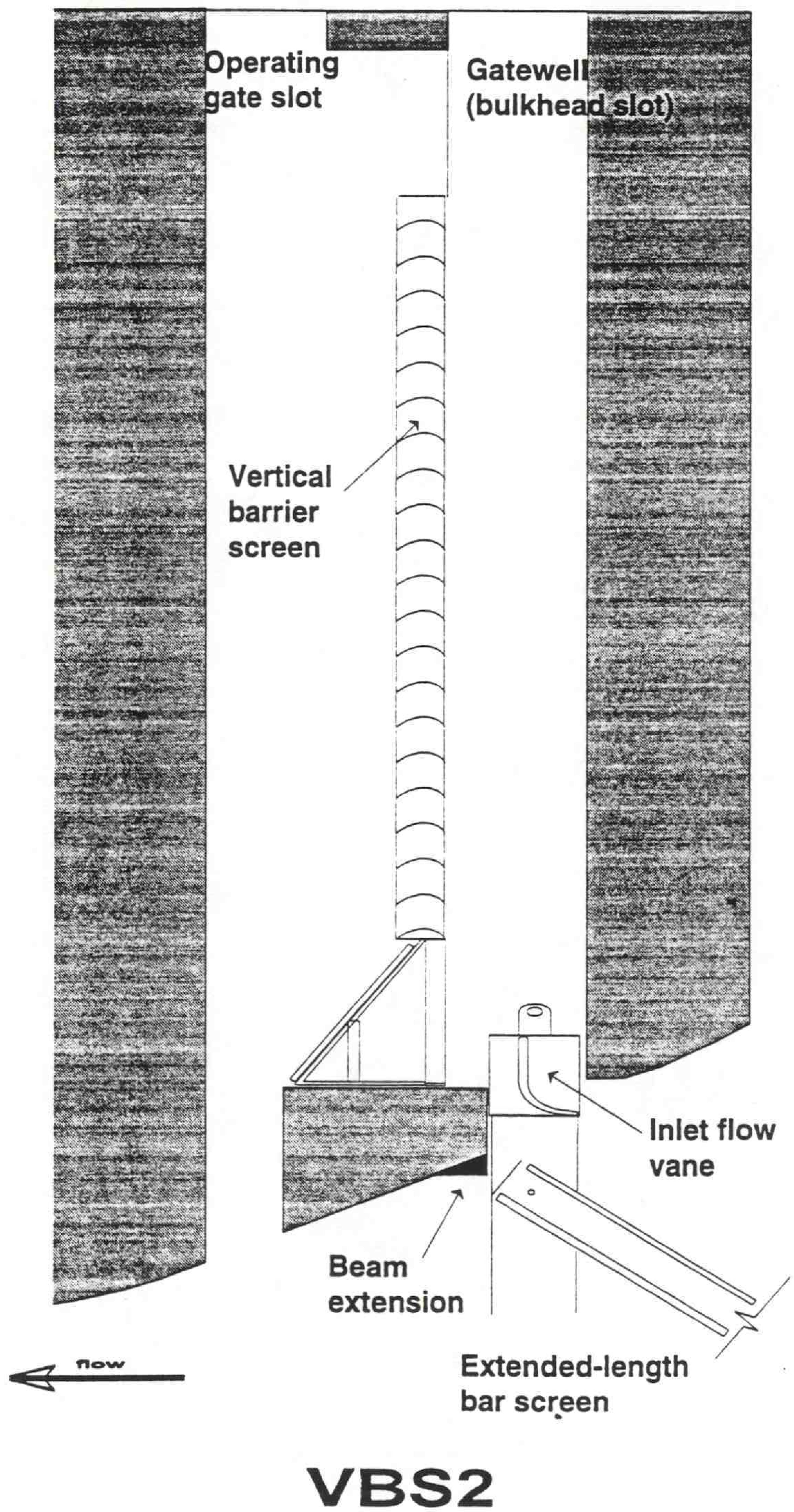

Figure 2. Cross section of vertical barrier screen design (VBS2), inlet flow vane, and beam extension used in Turbine Unit 4 at Lower Granite Dam, 1995.

objective was to determine the effects of these guidance system modifications on descaling of juvenile salmonids.

OBJECTIVE 1: MEASURE AND COMPARE ORIFICE PASSAGE EFFICIENCY OF NORTH AND SOUTH ORIFICES WITH AN EXTENDED-LENGTH BAR SCREEN, NEW VERTICAL BARRIER SCREEN, AND INLET FLOW VANE

Approach

Two entirely different methods of measuring OPE were used: 1) orifice traps, and 2) releases of passive integrated transponder (PIT)-tagged fish.

Orifice Trap

To count the number of fish exiting an orifice within 24 hours of release, orifice traps (1,533-l capacity) were installed in the north and south orifices of Slot 4B (Fig. 3). To start each test, at 1200 h all fish were removed from Gatewell 4B using a modified dip basket. Then, either the north or south trap was lowered into position and the respective orifice opened. Once an hour during the 24-hour test, the orifice was closed (for approximately 5 minutes) and the fish were crowded into a separate transfer box (639-l capacity) that was then raised and emptied of fish. The catch was anesthetized using MS 222 for species identification and enumeration, held in a recovery box (757-l capacity), and then released back into the collection channel. After 24 hours, the orifice was closed and residual fish were removed from the gatewell and counted. Orifice passage efficiency for each species was calculated by dividing the trap catch by the total number of fish of that species entering the gatewell slot during the 24-hour period (trap plus gatewell fish).

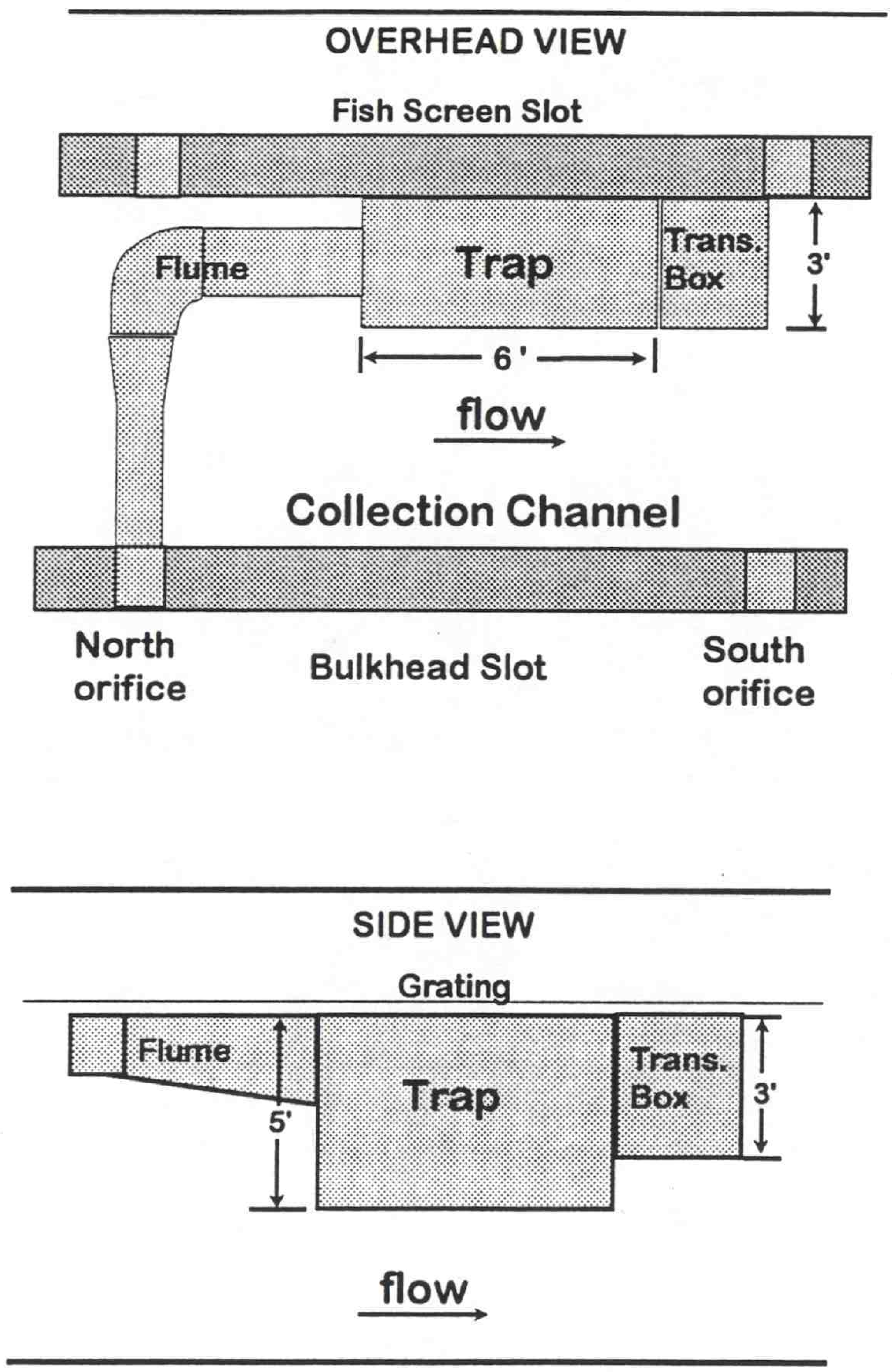

Figure 3. Overhead and side views of orifice trap attached to north orifice of Slot 4B in collection channel at Lower Granite Dam, 1995.

$$OPE = \frac{T}{T + GW} \times 100\%$$

T = Trap catch
GW = Gatewell catch

PIT-tag Releases

Fish for the PIT-tag release studies were taken from the Lower Granite Dam collection/transportation facility. For each release, 100 fish were anesthetized, PIT tagged, and placed in a release canister (1,211-l aluminum cylinder) that was transported by truck to the forebay deck. Fish were allowed to recover in the release canister for 24 hours before release into the gatewell or collection channel. The gatewell releases were made by releasing fish from the canister 15.2 m (50 ft) under the water surface (el. 687 ft M.S.L.) in Gatewell 4B. The collection channel releases were made simultaneously with the gatewell releases, with fish released into the collection channel adjacent to Gatewell 4B.

As the PIT-tagged fish entered the juvenile fish collection/transportation facility they were detected and the entry time was recorded by PIT-tag detectors located on the exit pipes of the wet separator. Then, for each release, the median passage time (time for half of the fish to reach the detector) was calculated. The estimated amount of time spent in the gatewell was calculated for each fish by subtracting the median collection-channel-to-detection time from its gatewell-to-detection time. Orifice passage efficiency was then estimated as the percentage of gatewell-released fish that spent less than 24 hours in the gatewell.

Results

Orifice Trap

During the 1995 spring outmigration, three OPE tests were conducted using the orifice trap (Table 1). In these tests, mean OPE for yearling chinook salmon and steelhead was 97 and 98%, respectively. Since the test orifice was switched from north to south after 18 hours of the third test, only the first two dates were used to compare the performance of the north and south orifices. On these dates, OPEs were identical in the north and south orifices for both yearling chinook salmon and steelhead.

PIT-tag Releases

Three releases of PIT-tagged yearling chinook salmon were made: two into Gatewell 4B and one into the collection channel. For PIT-tagged steelhead, one release was made into each location (Table 2). The mean orifice passage efficiencies for the gatewell releases (92 and 96% for yearling chinook salmon and steelhead, respectively) were slightly lower than estimates derived from orifice trap tests.

The averaged median gatewell-to-detection passage time for yearling chinook salmon was 2 hours, 20 minutes and the one median passage time for steelhead was 4 hours, 56 minutes. The median passage times for the collection channel releases (32 and 49 minutes for yearling chinook salmon and steelhead, respectively) indicated that neither species was delaying in the collection channel.

Diel Fish Movement

Because fish collected in the orifice trap during OPE tests were counted on a hourly basis, these tests also provided information on diel fish movement through the powerhouse (Fig. 4). The main period of fish movement during these tests was from 2000 h to

Table 1. Number of fish collected in north and south orifice traps, total number of fish collected in traps plus gatewell, and twenty-four hour orifice passage efficiency (OPE) for yearling chinook salmon and steelhead at Lower Granite Dam, 1995.

		Yearling Chinook			Steelhead		
Date	Loc.	Trap	Total	OPE (%)	Trap	Total	OPE (%)
4/17	N	9,405	9,496	99	2,244	2,256	99
4/18	S	7,831	7,908	99	2,522	2,535	99
4/19	N[a]	7,256	7,688	94	2,294	2,411	95

[a] Switched to south orifice at 0600 (18th hour) because of broken winch.

Table 2. Twenty-four hour orifice passage efficiency and median passage times for yearling chinook salmon and steelhead PIT tagged and released into the gatewell of Slot 4B and the collection channel (CC) adjacent to Slot 4B and then detected at the juvenile fish facility at Lower Granite Dam, 1995.

Date rel.	Time	Species	Rel. site	No. rel.	No. detected	OPE (%)	Med. time
5/05	1000	Chin.	Gtwell	99	88	88.9	1 h 20 min
5/05	1000	Chin.	CC	100	99	----	32 min
5/12	1000	Chin.	Gtwell	98	93	94.9	3 h 19 min
5/19	1300	Sthd.	Gtwell	98	94	95.9	4 h 56 min
5/19	1300	Sthd.	CC	100	99	----	49 min

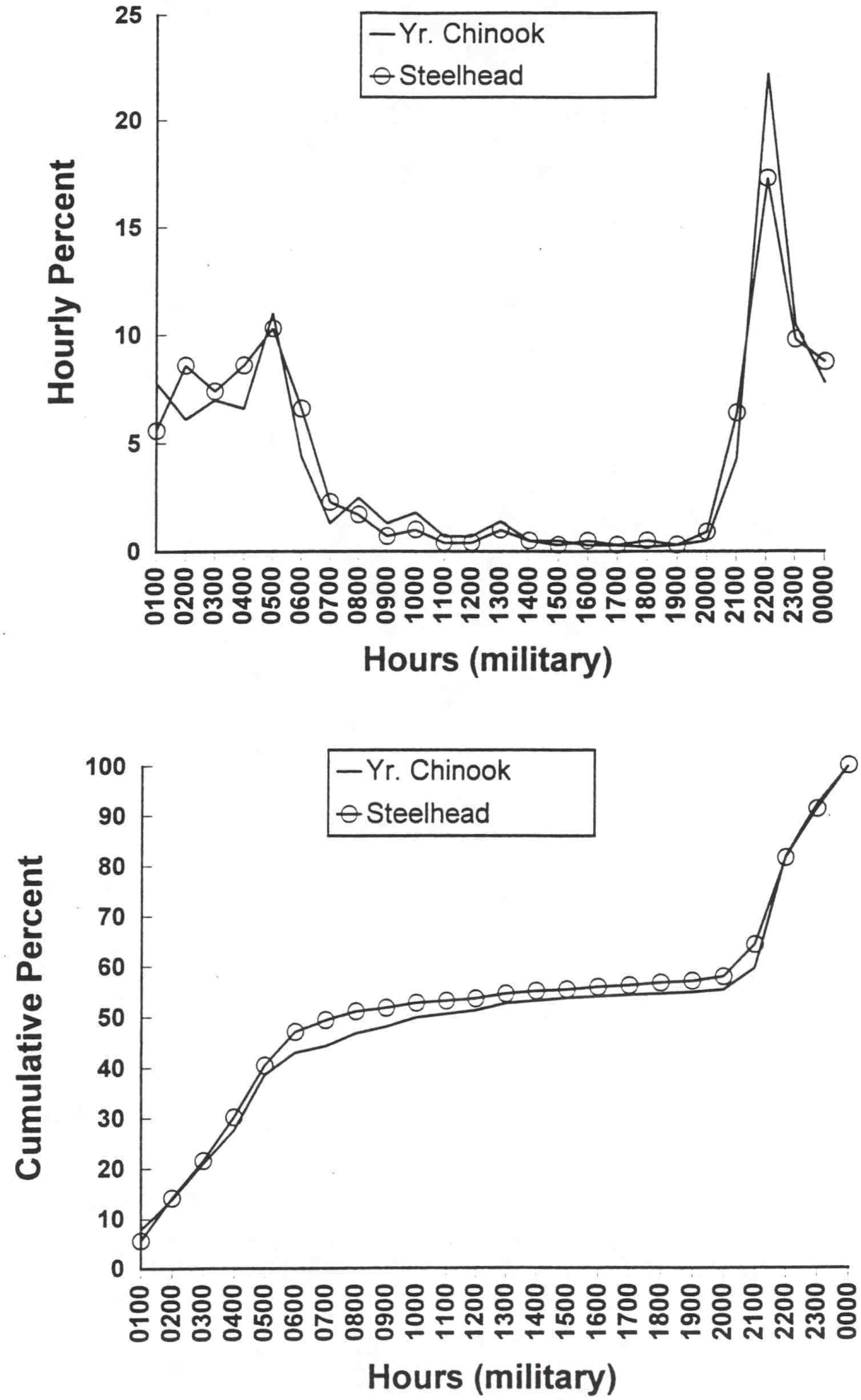

Figure 4. Hourly and cumulative percent passage of yearling chinook salmon and steelhead from the gatewell to the orifice trap at Lower Granite Dam, 1995.

midnight, with a smaller peak from 0400 to 0700 h. Approximately 50% of the daily passage occurred between 2000 h and midnight for the three nights tested. The hourly fish counts for all three tests are provided in Appendix Table 1.

Discussion

Although Slot 4B is only 1 of 18 slots in the Lower Granite Dam powerhouse, the number of fish collected by the orifice trap during the 24-hour tests was approximately 10% of the fish collected at the Lower Granite Dam collection/transportation facility. This was due both to powerhouse operation (only 4 or 5 turbine units were in operation, with no spill) and the fact that Unit 4 is close to the middle of the river channel, where yearling chinook salmon and steelhead migrants concentrate. In addition, this higher-than-expected percentage may also have been partly due to higher FGE of the ESBS in Slot 4B (See Table 3 which indicates much higher numbers of fish in Unit 4 versus Unit 5). Therefore, because of the high levels of OPE in the initial three tests and to lower the potential impact caused by the handling and anesthetizing of increasing numbers of fish, the decision was made to discontinue orifice trap tests and use releases of PIT-tagged fish into Gatewell 4B to continue the evaluation.

Although the number of orifice trap tests was limited, the fairly close agreement in results of the trap tests and the PIT-tag releases indicated an OPE of over 90% for both yearling chinook salmon and steelhead. These results were comparable to those obtained by Swan et al. 1984 with a 0.3-m (12-inch) orifice. The high OPEs we obtained with 0.25-m (10-inch) orifices indicate that the ESBS and VBS2 create currents within the gatewell that probably do not provide sanctuary areas for fish within the gatewell, but expedite passage through the orifice.

OBJECTIVE 2: EVALUATE THE EFFECTS OF AN EXTENDED-LENGTH BAR SCREEN, NEW VERTICAL BARRIER SCREEN, AND INLET FLOW VANE ON JUVENILE SALMONID DESCALING

Approach

To measure adverse effects caused by the ESBS or VBS2, daily samples of juvenile salmonids were collected from the gatewell of Slot 4B and examined for injuries and descaling. For comparison, samples were also collected and examined from the gatewell of Slot 5B, in which an STS was installed (with a modified balanced-flow VBS and raised operating gate). At 2000 h, 100 to 200 yearling chinook salmon and steelhead were collected from both Slots 4B and 5B, anesthetized, and examined for descaling and injuries. On most test days, fish were sampled again at 2200 h in Slot 4B to determine if descaling increased in fish that might have spent more time in the gatewell before exiting. A fish was determined to be descaled if cumulative scale loss exceeded 20% on either side (Ceballos et al. 1992). Paired t-tests were used to compare the differences in descaling between fish from the two slots and between fish collected at 2000 and 2200 h.

Results

For yearling chinook salmon, the difference in descaling between Slots 4B and 5B was negligible (Table 3). For steelhead, the difference in descaling was 0.2% which also was not statistically significant ($t = 0.21$, $df = 18$, $P = 0.8333$).

In the samples taken at 2000 and 2200 h, the difference in descaling for yearling chinook salmon was 0.2% which was not significant ($t = 0.47$, $df = 17$, $P = 0.6433$) (Table 4). For steelhead, the difference in descaling was 0.6% which also was not significant ($t = 0.98$, $df = 17$, $P = 0.3429$).

Table 3. Number examined, percent descaling, degrees of freedom, and t values for yearling chinook salmon and steelhead in Slots 4B (with extended-length bar screen, new vertical barrier screen, and inlet flow vane) and 5B (with standard-length submersible traveling screen).

	4B		5B			
Species	No.	Desc.(%)	No.	Desc.(%)	df	t
Yr. Chin.	6,650	0.8	3,862	0.8	22	0.03
Steelhead	6,013	3.9	3,338	4.1	18	0.21

Table 4. Number examined, percent descaling, degrees of freedom, and t values in Slot 4B (with extended-length bar screen, new vertical barrier screen, and inlet flow vane) for yearling chinook salmon and steelhead sampled at 2000 and 2200 h.

	2000		2200			
Species	No.	Desc.(%)	No.	Desc.(%)	df	t
Yr. Chin.	2,160	1.1	2,871	0.9	17	0.47
Steelhead	2,490	3.5	2,770	4.1	17	0.98

CONCLUSIONS

1) With an extended-length submersible bar screen, VBS2, and an inlet flow vane, OPE was over 90% for yearling chinook salmon and steelhead. There was no statistically significant difference in OPE between the north and south orifices.

2) Descaling with the test guidance devices was low (<1% for yearling chinook salmon and <4% for steelhead) and was not significantly different from descaling with a standard-length submersible traveling screen.

3) During three OPE tests using orifice traps, approximately 50% of the daily juvenile salmonid passage occurred between 2000 h and midnight.

4) The results of PIT-tag releases indicated that neither yearling chinook salmon nor steelhead were delaying for extended periods of time in the gatewell or collection channel.

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APPENDIX TABLES

Appendix Table 1. Numbers of yearling chinook salmon and steelhead collected hourly and percent of total collection, during orifice passage efficiency tests using orifice traps at Lower Granite Dam, 1995.

	YEARLING CHINOOK SALMON				
TIME	Apr 17	Apr 18	Apr 19	TOTAL	%
1300	160	70	118	348	1.42
1400	74	12	32	118	0.48
1500	42	24	58	124	0.51
1600	13	14	35	62	0.25
1700	18	20	32	70	0.29
1800	23	11	24	58	0.24
1900	35	12	17	64	0.26
2000	43	29	51	123	0.50
2100	490	336	214	1,040	4.25
2200	2,558	1,763	1,124	5,445	22.23
2300	1,108	878	596	2,582	10.54
2400	597	495	816	1,908	7.79
100	720	862	334	1,916	7.82
200	405	485	614	1,504	6.14
300	568	602	552	1,722	7.03
400	883	497	234	1,614	6.59
500	1,066	635	996	2,697	11.01
600	425	343	304	1,072	4.38
700	66	123	135	324	1.32
800	12	329	280	621	2.54
900	45	125	138	308	1.26
1100	31	71	332	434	1.77
1200	23	95	220	338	1.38
TOTAL	**9,405**	**7,831**	**7,256**	**24,492**	**100**

Appendix Table 1. Continued

	STEELHEAD				
TIME	Apr 17	Apr 18	Apr 19	TOTAL	%
1300	46	13	8	67	0.95
1400	26	5	7	38	0.54
1500	15	3	1	19	0.27
1600	24	5	4	33	0.47
1700	14	3	5	22	0.31
1800	18	9	5	32	0.45
1900	13	7	4	24	0.34
2000	40	9	16	65	0.92
2100	152	173	129	454	6.43
2200	406	466	350	1,222	17.31
2300	181	255	252	688	9.75
2400	165	145	309	619	8.77
100	189	158	45	392	5.55
200	123	248	234	605	8.57
300	164	230	127	521	7.38
400	229	322	57	608	8.61
500	253	201	272	726	10.28
600	138	146	182	466	6.60
700	19	49	94	162	2.29
800	1	39	78	118	1.67
900	8	9	33	50	0.71
1100	4	14	53	71	1.01
1200	16	13	29	58	0.82
TOTAL	**2,244**	**2,522**	**2,294**	**7,060**	**100**

Appendix Table 2. Total numbers and percent descaling for all fish examined in Unit 4 at Lower Granite Dam, 1995.

			Chinook			Steelhead		
Date	Time	Slot	Desc.	Exam.	%	Desc.	Exam.	%
4/15	2000	4B	1	246	0.4	0	79	0.0
4/16	2000	4B	4	204	2.0	2	125	1.6
4/17	2000	4B	0	41	0.0	0	12	0.0
4/18	2000	4B	3	77	3.9	0	13	0.0
4/19	2000	4B	1	252	0.4	1	27	3.7
4/20	2000	4B	4	239	1.7	3	85	3.5
4/21	2000	4B	0	206	0.0	3	166	1.8
4/24	2000	4B	3	131	2.3	2	110	1.8
4/24	2200	4B	1	210	0.5	1	44	2.3
4/25	2000	4B	0	93	0.0	1	175	0.6
4/25	2200	4B	0	188	0.0	2	183	1.1
4/26	2000	4B	2	180	1.1	3	168	1.8
4/26	2200	4B	2	167	1.2	1	188	0.5
4/27	2000	4B	0	225	0.0	2	99	2.0
4/27	2200	4B	1	237	0.4	1	122	0.8
4/28	2000	4B	3	284	1.1	0	117	0.0
5/1	2000	4B	4	256	1.6	0	23	0.0
5/1	2200	4B	2	215	0.9	0	128	0.0
5/2	2000	4B	4	172	2.3	3	118	2.5
5/2	2200	4B	2	190	1.1	4	230	1.7
5/3	2000	4B	0	78	0.0	7	182	3.8
5/3	2200	4B	4	190	2.1	5	263	1.9
5/4	2000	4B	2	214	0.9	1	121	0.8
5/4	2200	4B	5	235	2.1	0	58	0.0

Appendix Table 2. Continued

			Chinook			Steelhead		
Date	Time	Slot	Desc.	Exam.	%	Desc.	Exam.	%
5/8	2000	4B	2	106	1.9	10	248	4.0
5/8	2200	4B	2	156	1.3	7	274	2.6
5/9	2000	4B	1	125	0.8	0	142	0.0
5/9	2200	4B	4	260	1.5	2	49	4.1
5/10	2000	4B	1	77	1.3	10	171	5.8
5/10	2200	4B	0	221	0.0	2	82	2.4
5/11	2000	4B	1	69	1.4	3	130	2.3
5/11	2200	4B	1	113	0.9	7	211	3.3
5/15	2000	4B	0	62	0.0	11	177	6.2
5/15	2200	4B	0	116	0.0	7	155	4.5
5/16	2000	4B	2	137	1.5	5	169	3.0
5/16	2200	4B	0	70	0.0	10	185	5.4
5/17	2000	4B	0	80	0.0	8	148	5.4
5/17	2200	4B	2	62	3.2	15	175	8.6
5/22	2000	4B	1	38	2.6	3	107	2.8
5/22	2200	4B	0	52	0.0	8	111	7.2
5/23	2000	4B	1	79	1.3	8	91	8.8
5/23	2200	4B	0	75	0.0	19	144	13.2
5/24	2000	4B	0	38	0.0	13	111	11.7
5/24	2200	4B	1	114	0.9	23	168	13.7
5/25	2200	4B	0	70	0.0	14	129	10.9

Appendix Table 3. Total numbers and percent descaling for all fish examined in Unit 5 at Lower Granite Dam, 1995.

			Chinook			Steelhead		
Date	Time	Slot	Desc.	Exam.	%	Desc.	Exam.	%
4/15	2000	5B	2	354	0.6	0	25	0.0
4/16	2000	5B	3	230	1.3	1	21	4.8
4/18	2000	5B	7	224	3.1	3	100	3.0
4/19	2000	5B	2	212	0.9	3	38	7.9
4/20	2000	5B	4	306	1.3	1	14	7.1
4/21	2000	5B	2	208	1.0	0	5	0.0
4/24	2000	5B	3	226	1.3	6	218	2.8
4/24	2200	5B	0	203	0.0	3	122	2.5
4/25	2000	5B	0	54	0.0	0	201	0.0
4/25	2200	5B	1	227	0.4	3	115	2.6
4/26	2000	5B	2	154	1.3	2	209	1.0
4/26	2200	5B	0	159	0.0	1	293	0.3
4/27	2000	5B	0	88	0.0	5	369	1.4
4/27	2200	5B	1	205	0.5	0	111	0.0
4/28	2000	5B	0	24	0.0	2	245	0.8
5/1	2000	5B	0	193	0.0	0	131	0.0
5/1	2200	5B	2	258	0.8	0	62	0.0
5/22	2200	5B	2	86	2.3	16	201	8.0
5/23	2000	5B	2	66	3.0	25	206	12.1
5/23	2200	5B	1	134	0.7	18	185	9.7
5/24	2000	5B	0	51	0.0	15	144	10.4
5/24	2200	5B	1	134	0.7	14	177	7.9
5/25	2200	5B	0	66	0.0	16	146	11.0